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TRAINING EXTENSION COURSE RESEARCH: Review of the Literature on Cost and Training Effectiveness

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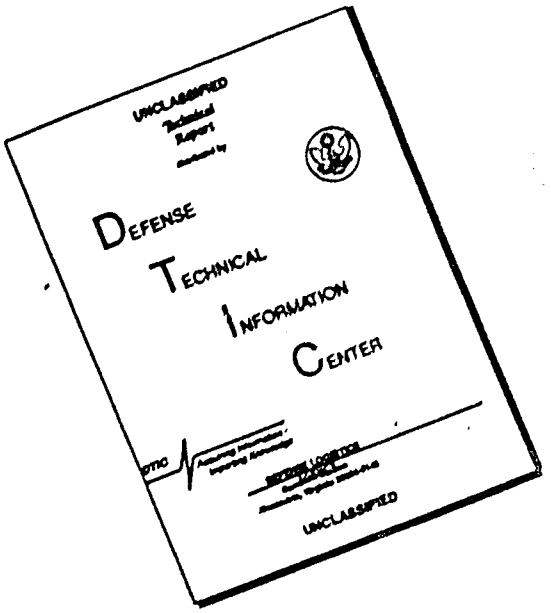

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This report gives a review and evaluation of literature in the field of cost and training effectiveness as an introduction to considering the development of a Cost and Training Effectiveness Analysis (CTEA) methodology for the Army's Training Extension Course (TEC) program. Five methodological requirements for a TEC CTEA are specified, and use of the methods of microeconomics and welfare economics to approach the methodological requirements is suggested. Finally, the logic of a TEC CTEA methodology under these precepts is discussed. (Developments and details are to be presented in a subsequent report.)

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LITERATURE REVIEW: COST AND TRAINING EFFECTIVENESS

INTRODUCTION

This report is one in a series of documents dealing with cost and training effectiveness of the Training Extension Course (TEC) Program. This document reports on a review and evaluation of literature with the objective of identifying State-of-the-Art methods and techniques applicable, in whole or part, to the performance of Cost and Training Effectiveness Analyses (CTEA).[1] The review included literature from all available military and non-military sources. Specifically, the purpose of the review was to identify those approaches which have been productive with respect to training systems evaluations and to identify where discrepancies in methods and techniques exist. The scope of this review is limited to that literature having some bearing on methodology useful to the evaluation of TEC.

A following document will describe the methodology formulated, in light of this review, to carry through a TEC CTEA. It also will contain an assessment of that methodology with regard to its strong and weak points. Finally, that document will describe application of the methodology to a set of hypothetical cost and training data. Thus, this present document can be viewed as background and introduction to that document.

CTEA CONCEPT

TEC was designed as a series of multimedia, exportable, performance-oriented training packages. Its purpose is to provide high quality, uniform instruction in critical skills to individual and small groups of soldiers (Litton Systems, Inc., 1978).

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[1] Throughout this report the phrases CTEA, evaluation of TEC, and training (program) evaluation are used. These phrases are not synonymous, though they are closely related. CTEA refers to an evaluation of a training program using methodology consistent with the Army's, as set forth in the TRASANA (U. S. Army TRADOC Systems Analysis Activity) CTEA Handbook. Evaluation of TEC refers, in general, to any assessment (not necessarily consistent with Army CTEA methodology) of the TEC program. In context, however, we always accept that an evaluation of TEC will be consistent with CTEA methodology. Training (program) evaluation refers to any methodology. Training (program) evaluation refers to any assessment of any type of any training program. CTEA is a special case of training (program) evaluation, and TEC CTEA is a special case of evaluation of TEC.

GENERAL REQUIREMENTS

A TEC CTEA must involve, as does any CTEA, a comparison of the effectiveness and costs of alternative training systems. In addition to examining a program of instruction (such as TEC), a CTEA can also examine training concepts, training equipment, training strategies, training organization and facilities, and training impacts of new material, organizations or tactics (TRASANA, 1976). Ultimately, any decision regarding a modification of any part of the training system must be made in consideration of the effects of that modification on the effectiveness of the force structure. Thus, a CTEA must relate a (proposed or actual) change in the training system to its ultimate impact on combat effectiveness. There should be a clear "audit trail" from the former to the latter. This means the CTEA must be performance-oriented. There are three basic types of CTEA: the Train-up Study (TUS), the Training Analysis for COEA[2] (TAC), and the Training Development Study (TDS). This final type of CTEA is conducted to evaluate and compare training effectiveness, resource impacts, costs, and cost benefits of alternative training systems proposed to correct training deficiencies, to facilitate attainment of individual and collective performance objectives, or to achieve training economies (TRASANA, 1976). The evaluation of TEC is a TDS-type CTEA.

In any CTEA, the proposed alternative must be compared with the baseline system, which is the best currently available training system. The comparison can be of three different types: fixed cost, variable effectiveness; variable costs, fixed effectiveness; or variable costs, variable effectiveness. In the TEC case, the comparison is of the third variety.

Because TEC is designed to complement, or enhance, existing training systems; and not (necessarily) to substitute for any part of the extant training system; a TEC CTEA must reflect that complementary nature. This means we must explicitly recognize that, a purpose of TEC being to enhance effectiveness, a "fixed effectiveness" type of CTEA methodology would be inappropriate for TEC evaluation. At the same time, notwithstanding the fact that minimizing training costs is an important goal, TEC is not necessarily intended as a dollar-for-dollar replacement for any existing training expenditures. Thus, a "fixed cost" type of CTEA methodology for TEC would also be inappropriate. What remains, then, is that the TEC CTEA methodology must be a "variable cost, variable effectiveness" type of comparison. Such a comparison is usually referred to as a cost benefit analysis.

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[2] Cost and Operational Effectiveness Analysis.

In contrast, when either cost or effectiveness is held fixed, that comparison is called a cost effectiveness analysis (Sassone and Shaffer, 1978).

The methodological requirements for a TEC CTEA are dictated by the usual CTEA considerations (TRASANA, 1976) as well as by the TEC CTEA's kinship to a cost benefit analysis (Mishan, 1976; Sassone and Shaffer, 1978). Five requirements can be identified:

- o the baseline training system must be identified and its parameters quantified
- o the training system inclusive of TEC must be defined and its parameters quantified
- o an input cost function must be developed which maps any training system configuration into its dollar cost
- o an effectiveness production function must be developed which maps any training system configuration into an objective measure of its effectiveness
- o an approach must be devised which objectively translates changes in effectiveness into corresponding dollar values.

PROPOSED APPROACH FOR TEC

The methods of microeconomics and welfare economics can be used to approach the methodological requirements for a TEC CTEA. The evaluation procedures are objective, and result in ultimate dollar valuations of the TEC training concept.

In the context of military training, a model can be set up as follows. A group (person, platoon, company, battalion, etc.) has a number of missions for which it is responsible. There are a number of different types of training activities in which the group can engage, and each type of training activity makes some contribution to the ability of the group to carry out each mission. To be sure, certain types of training may enhance ability in one mission area more than in another. Each training activity is conducted in self-contained "units" so it is meaningful to measure the amount of training a group receives as a number of units of each type training. The overall ability and proficiency with which the group carries out its assigned missions is referred to as the group effectiveness, and we assume a reasonable objective measure of group effectiveness exists. The costs of carrying out each type of training are also assumed to be known, and the group's training budget is assumed known and fixed.

Suppose a new training concept is developed and is considered for introduction into this milieu. A procedure is needed to determine whether, and to what extent, the new training concept is economically viable. The basic approach is to determine whether the present value of the sum of the net values of the new training to each group utilizing that training over the "lifetime" of the training program exceeds the development cost of the training program. The key to implementing the approach is the determination of the net value of the new training to a group using it. This can be accomplished using either one of two concepts from welfare economics. The first is the compensating budget variation (Currie, et. al., 1971). Here one attempts to determine the maximum training budget reduction a group can suffer in the presence of the new training program which still permits the previous level of effectiveness - the level reached with the initial budget and no new training - to be achieved. The second concept is the equivalent budget variation. Here one attempts to determine the minimum training budget increase which a group must receive to achieve the same increase in effectiveness without the new training program as can be achieved with the initial budget and with the new training program. Under certain conditions, the compensating budget variation and the equivalent budget variation are numerically equivalent. More generally, however, the latter exceeds the former.[3] Which of the two concepts provides the more appropriate measure of the value of the new training program depends on the objective of the organization. If the objective is to minimize the cost of achieving the current level of effectiveness, the compensating budget variation is more appropriate. If the objective is to increase effectiveness while maintaining the initial budget level, the equivalent budget variation is more appropriate. To the extent that the organization's objective is uncertain, or to the extent it combines both mentioned objectives, a weighted average of the two variations can be used.

The numerical values of both the compensating and equivalent budget variations can be derived from the effectiveness production function and the group's training budget constraint (or input cost function). The effectiveness production function is the relationship between the inputs and output of the training process.[4] The

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[3] The reason for this asymmetry, which was first pointed out by A. Henderson ("Consumers Surplus and the Compensating Variation", Review of Economic Studies, 1941) is somewhat technical and unimportant for present purposes.

[4] Here we are using concepts borrowed from the theory of production in economics. See Henderson and Quandt, 1971; Takayama, 1974; Intriligator, 1971.

inputs are the various types and amounts of training the group receives, along with the relevant attributes of the group itself (such as intelligence and prior training); the output is the assumed, objective and measurable characteristic, effectiveness. The training budget constraint is the relationship among the dollar value of the training budget, the unit costs of the various types of available training, and the quantities of each type of training which can be afforded.

The training budget constraint is a linear function and is conceptually straightforward. The effectiveness production function, on the other hand, is (in general) non-linear and is rich in possible specifications. In considering the impact on the production function of the introduction of a new training program, there appear to be four distinctly different ways in which the new program can affect effectiveness. First, the new program can influence effectiveness in the same way that every other program does, i. e., it is simply another among many training programs. Second, the new program can enhance or augment the effect of one or several of the other training programs, i. e., it can make it seem like more of some other training is being received than is actually the case. Third, the new program can uniformly augment all the other training, i. e., it can raise the entire effectiveness production function. Finally, the new training program can increase the substitutability of one type of training for another, permitting some of a less costly type of training to be substituted for some of a more costly type of training while maintaining the initial level of effectiveness.

The effectiveness production function must be empirically determined. Multiple regression analysis is the logical starting point for this estimation process. The observations (data points) may be cross-sectional or longitudinal, or perhaps a pooled sample. The regressand is the effectiveness measure achieved by the group. The regressors would be the amounts of each type of training, as well as such standardizing variables as intelligence and prior training, relevant to each effectiveness observation. The training budget constraint need not be empirically estimated, but can be constructed using available data.

The details and development of a TEC CTEA methodology based on this approach will be presented in a subsequent report.

LITERATURE REVIEW

As mentioned at the outset, this survey and discussion of literature is motivated by the goal of carrying out a Cost and

Training Effectiveness Analysis of the Army's Training Extension Course Program. CTEA methodology is now in the formative stage. It was quite naturally hoped that a review of relevant methodology oriented literature would provide information, concepts, and techniques useful to the development of a TEC CTEA methodology. Thus, the objective of the research effort reported here is to evaluate recent literature with regard to its applicability to the TEC CTEA problem.

LITERATURE SEARCH

Two more or less separate bodies of literature were searched for TEC CTEA - relevant material. The first body was the training evaluation literature. This literature, comprised primarily of military documents, is problem oriented. It generally focuses on a specific training program. In contrast, the second body of literature was primarily theoretical in orientation. This was the economic evaluation literature, comprised of monographs and journal articles dealing with the general economic considerations of evaluating any type of program or project. Because of inherent differences between these two bodies of literature, different search procedures were used in each case to ferret out TEC-relevant material. For the training literature, computerized literature searches were employed to generate extensive lists of titles and abstracts. These were screened on the basis of apparent TEC relevance, and thus a set of documents was chosen for detailed review. The economic evaluation literature was selected from the subject classification indices of the Journal of Economic Literature, from the bibliographies of recent comprehensive monographs in project evaluation, and from among the well-known "classics" of the field.

TRAINING LITERATURE

The approach adopted for the training literature survey is not entirely orthodox. Recognizing that a TEC CTEA would involve numerous complexities, subtleties, and abstract concepts; it was not perfectly obvious that truly relevant (or, for that matter, irrelevant) training literature would be recognized as such. Thus, a classification scheme for both training issues and training literature was devised. It was hoped that by identifying the class of issues of which a TEC CTEA would be but one example, TEC-relevant literature could be identified as all literature dealing with that class of issues. Based on a "resources - effectiveness hierarchy", a cause-effect model linking resources to battalion effectiveness through a number of intermediate steps, four classes of training-relevant issues were identified. These classes, developed and discussed in the next section, were then

used to categorize the training literature abstracts (see Appendix).

The results of the literature survey were mixed. Methodology directly and specifically applicable to the evaluation of the TEC program was not uncovered in the course of the survey. While some of the concepts and techniques which surfaced should provide general guidance, and while others should prove useful as part of an eventual TEC CTEA methodology, that TEC-specific methodology apparently still awaits construction.

Framework for Assessment of Training Literature.

Our objective in this section is to develop a convenient framework, or set of logical categories, by which to organize the vast literature dealing with evaluation of training. The motivation for this taxonomy is to better determine which literature can apply to the evaluation of the TEC program, by noting where in the taxonomy TEC fits; and then noting the corresponding literature. Our approach is to first construct a conceptual hierarchy relating resources to battalion effectiveness, then to categorize training issues with reference to the hierarchy; and finally to discuss the relation of the TEC assessment to the hierarchy.

The Resources-Effectiveness Hierarchy.

Figure 1 illustrates the Resources-Effectiveness Hierarchy. It indicates (starting at the base) that various resources are used to produce various training programs. The set braces, {}, indicate there is a set of resources and a set of training programs. In general, each training program is produced from a subset of the resources, and particular resources may be used in more than one training program. The next step up the hierarchy suggests that various training programs produce various individual task proficiencies. The process continues up to the top step which suggests that battalion proficiency in its various missions contributes to a single ultimate measure of battalion effectiveness.[5]

Classes of Issues.

The Resources-Effectiveness Hierarchy is a convenient way to lend organization to the training literature, insofar as it sug-

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[5] The hierarchy of Figure 1 is hardly unique. Truncated or extended versions could easily be constructed. For what follows, the specific form of the hierarchy is not critical. We need only recognize the existence of some such hierarchy.

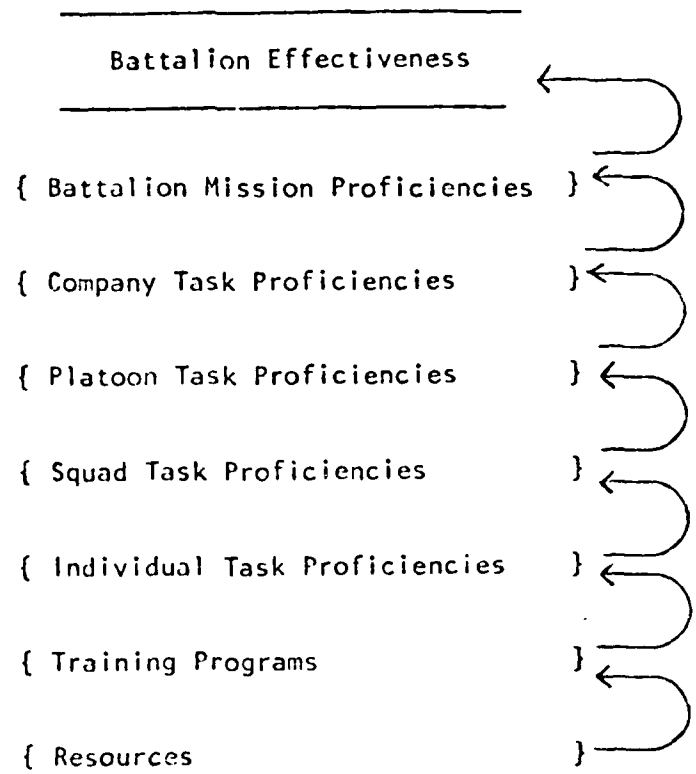

Figure 1. The Resources-Effectiveness Hierarchy

gests several (more or less) non-overlapping classes of training issues with which the literature is concerned. These classes of training issues can be described as follows.

Production Function Issues (Class I).

The Resources-Effectiveness Hierarchy actually represents a series of production functions. For example, letting A_1, A_2,... represent the various types of resources; B_1, B_2,... represent the various types of training programs; C_1, C_2,... represent the various types of individual skills; etc.; relationships of the following forms exist:

$$\bar{B}_i = B^i(A_1^i, A_2^i, \ldots) \qquad \forall_i$$

$$\bar{C}_i = C^i(B_1^i, B_2^i, \ldots) \qquad \forall_i$$

etc.

where $\bar{B}_i$ is the "quantity" of B_i produced, and A_j^i is the quantity of A_j used to produce $\bar{B}_i$, and likewise for $\bar{C}_i$ and B_j^i. Additionally, "nested" production functions exist:

$$\bar{C}_i = C^i(B^1(A_1^1, A_2^1, \ldots), B^2(A_1^2, A_2^2, \ldots))$$

which relate the elements of non-adjoining sets in the hierarchy.

A great deal of the training literature is concerned with production function issues, although the literature is rarely self-identified with that appellation. For example, literature dealing with questions like:

- does this training program contribute to these skills or tasks?
- which of these several training programs contribute most to this skill or this task?
- which resources best contribute to the development of certain skills?
- which individual task proficiencies contribute to group task proficiencies?

is, in fact, inquiring as to the arguments and form of one of the production functions suggested by Figure 1.

Cost Estimation Issues (Class II).

Associated with each element in each set in the hierarchy are cost estimation problems, such as:

- o what is the expected cost of a specific training program?
- o what has been the cost of producing specific levels of individual skills?
- o what is the range in costs of achieving a given level of platoon task proficiency?

Even a casual survey indicated a good deal of literature treats cost estimation issues.

Efficiency Issues (Class III).

By efficiency is meant how best to achieve some end. There are three types of efficiency issues:

- o Maximize Output given a prescribed level of costs for the inputs, and given the production function which determines the input/output possibilities.
- o Minimize Costs given a prescribed level of output, and given the production function.
- o Determine the Optimal Output/Cost combination given the minimum cost of any specified level of output.

Of these three types of efficiency issues, the first two are associated with the rubric cost-effectiveness analysis (CEA), while the third is known as cost-benefit analysis (CBA). Cost-effectiveness analyses, insofar as they deal with the manipulation of directly observable functions (cost and production), are usually conceptually straight-forward. On the other hand, cost-benefit analyses deal with the preferences (or utility) of a reference agent or organization. These preferences are largely unobserved, and must be somehow inferred. Needless to say, cost-benefit analyses are usually difficult to carry out.

Much of the training literature is concerned with efficiency issues, and most reports are of the cost-effectiveness variety.

Valuation Issues (Class IV).

A class of issues related to the preceding class is the valuation of hierarchical elements. For example, one might ask what the value of a specific training program is, or what the value of an increment in some task proficiency is. The link between this class and the previous one is that both directly address policy questions; both deal with determining what should be done - what type or level of training (or skill or task proficiency) should be achieved? Additionally, both deal with CEA and CBA. In this set of issues, CEA and CBA provide the methods to arrive at valuations. Two subclasses of issues may be identified here. These are where the program (or skill or task) to be valued is essentially a substitute for other programs which perform the same function; or where the program is essentially a complement to other programs, extending, amplifying, or reinforcing some skill levels or proficiencies. In the first case, where the program is a substitute for other programs, the methods of CEA may be used to determine value by computing cost savings or increases in output. In the second case, the more difficult procedures of CBA must be employed to derive a value.

The Training Extension Course (TEC) Program.

"TEC is a program that has been designed to help put into the hands of trainers, both in units and in institutions, exportable, performance-oriented training packages. It is designed to provide soldiers and their commanders with immediate access to high quality, self-paced, multimedia instruction especially designed to assist in acquiring and maintaining skills critical to the soldier's on-the-job performance. Each TEC lesson is individually packaged, and ready for use on an individual basis, or by small groups, under the supervision of an NCO.

"Historically, TEC began in the early 1970's as a response to a number of problems in individual training. The most serious of these was detected by the U. S. Army Board for Dynamic Training. They found that many soldiers in combat arms units were not able to perform critical tasks in their primary Military Occupational Specialty (MOS). This lack of competency on the part of individuals can quickly mushroom and destroy a unit's combat capability. In the process of considering solutions to this problem, many other problems were uncovered that confront commanders, training managers, and trainers. Some of these problems were:

- o insufficient numbers of qualified NCOs to conduct the required training
- o demands on the commander's time which interferred with training time

- o personnel turbulence such as frequent turnover and low manning levels
- o rapidly changing doctrine which necessitates changes in training
- o limited training resources such as the shortages of time, personnel, and space to provide sufficient field-based training.

"All of these problems underscored the need for a system of exportable training support that would make performance based, high quality instruction available to field units in an easy to use format. TEC was conceived as such a system" (Litton Systems, Inc., 1978).

The issue addressed by this research program is the value of the TEC program. The question at this point is where, in the foregoing issue taxonomy, does this research program fall? Clearly, it falls within our Issue Class IV. Moreover, because the TEC program is not designed as a substitute or replacement for any other specific training program, but rather is meant to enhance training in field units, our research program falls into the Complement subclass of Issue Class IV. This is not to suggest that TEC could not, will not, or does not substitute for some amounts of some other types of training in field units. What is meant is that insofar as at least some TEC usage is complementary, the value-determining methodology must be capable of evaluating TEC in its complementary role. This means that the methods of cost-benefit analysis, rather than simply cost-effectiveness analysis, must be brought to bear on the problem. Additionally, this means the evaluation of the TEC program can be expected to present the same substantial difficultites present in most cost-benefit studies.

These difficulties can be illustrated by reference to a vertically truncated but horizontally expanded version of the Resources-Effectiveness Hierarchy, such as in Figure 2. Suppose that individuals are currently receiving some Baseline Training Program to produce proficiency in some task, such as Task 2 in the figure. Suppose an alternative training program is proposed as a substitute for the baseline program. To value that proposed alternative program we need only determine whether that program achieves the same task proficiency at less cost. The difference in cost is the relative net value of the alternative program. The information requirements to carry out the analysis are limited to the cost functions for both training programs and the production functions linking each training program to individual task proficiencies. Such information re-

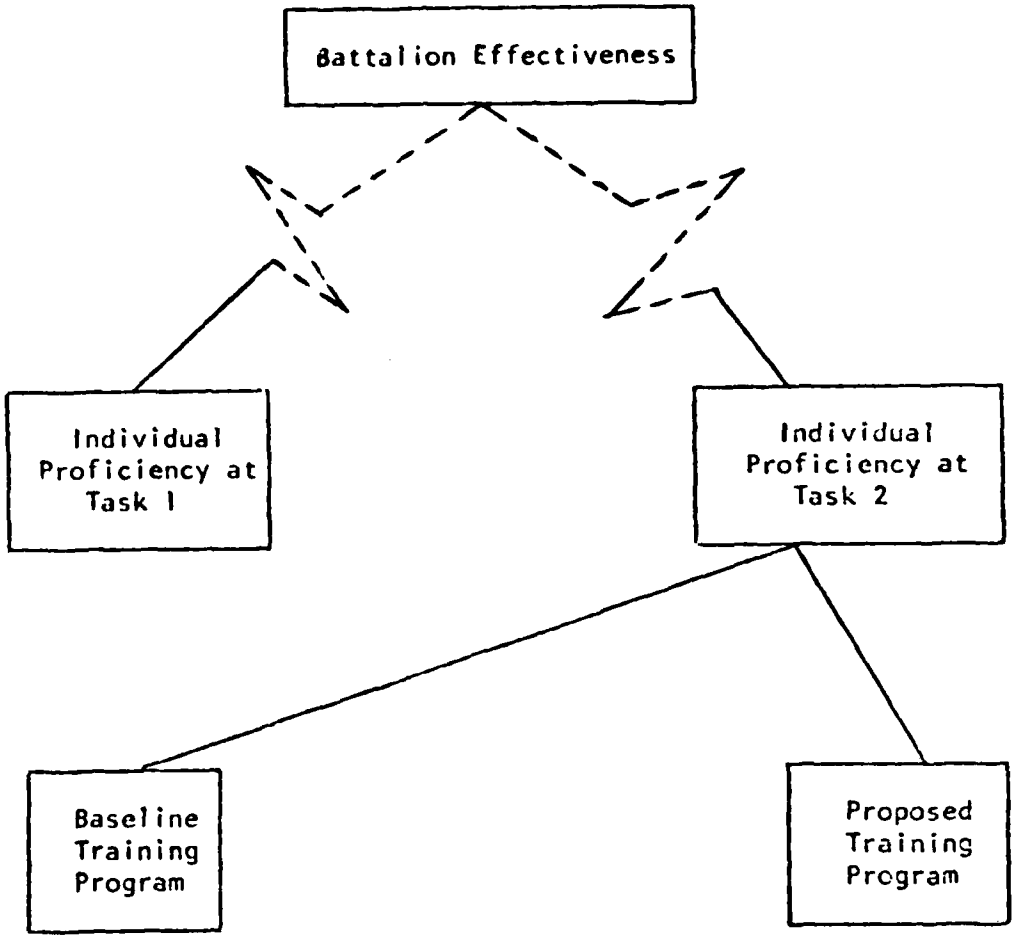

Figure 2. Alternative Representation of Resources-Effectiveness Hierarchy.

quirements are hardly trivial, yet they are substantially less than if the proposed program were intended, at least partially, to complement the baseline program. Insofar as complementarity is intended, then greater total program costs along with greater task proficiency is intended, and it is meaningless to ask whether the proposed program achieves the same task proficiency at less cost. What must be asked is whether the greater task proficiency is worth the greater cost. Note that the implied comparison between greater proficiency and greater cost is between magnitudes of entirely different dimensions. Note also that in the previous case where the proposed program is an alternative (i. e., substitute), the resulting comparison is between two costs - clearly involving the same dimension. Thus, the critical difference between the substitute case and the complement case is the resulting dimensionality of the magnitudes intended for comparison. This is largely the difference between CEA and CBA. The latter almost inherently deals with "incommensurables", while the former may not.

An Observation About Training Program Analysis.

When different dimensions arise in the course of a training program analysis, some transformation must be found to "map" each dimension into one common dimension. The common dimension is typically dollars and the transformation is sometimes known as "shadow pricing". While there are many shadow pricing techniques, in the case of training one would attempt to trace the effects of the greater task proficiency to some other set of effects which are amenable to dollar valuation, and by holding all other factors constant, ascribe that dollar value back to the training program under scrutiny.

This point can be clarified by example. Consider a vertically integrated firm which provides some of its own inputs to its production process rather than purchasing those inputs in the marketplace. Suppose that for some internal accounting or control purposes the firm wishes to place a meaningful dollar value (per unit) on one of its self-supplied inputs. The most reasonable approach is to trace the impact of that input through the production process and on the value of the final good(s) produced. The value of the input is its contribution to the value of the final product. In the parlance of traditional economics, this is the input's marginal revenue product; in the parlance of mathematical programming, this is the input's dual variable's value (Sassone, 1977).

Another example, somewhat closer in spirit to the issue at hand, would be the attempt to place a value on a computer based

instructional system used in a government vocational training program for low income civilians. If the object of the program is to increase the trainees' incomes, the value of the computer based instruction system would be its marginal contribution to the sum of the present value of the trainees' incomes.

In each of these examples, a single production function is involved, and the output of the production process is readily expressible in monetary terms. In the first example the production function is the relation between the firm's inputs and its final output, in the second example the production function is the relation between the resources used for training and the trainees' incomes. It is clear that in both cases outputs are easily expressed in dollar terms. The problems associated with imputing values to the inputs in these cases would revolve around the determination of the form of the specific production function involved - no mean task. Yet, these two cases are far simpler than the TEC case because:

- o TEC evaluation involves all the production functions depicted in the Resources - Effectiveness Hierarchy of Figure 1, not just one
- o the output of none of the production processes of Figure 1 is readily expressible in monetary terms

These complications mean that the effects of TEC must be traced through a number of production functions.

The more production functions become involved, the more variables must be standardized, the more tenuous become the relations, and the more errors are likely to find their way into the analysis. And at some point, an "effectiveness to dollars" transformation must be carried out. In sum, the requirements for the evaluation of a complementary training program, such as TEC, are very substantial; and the analysis is likely to be very difficult to carry out.

Discussion of Training Literature.

A review of both the military and the civilian training education literatures failed to uncover a training evaluation methodology directly applicable to TEC. This finding should not be construed as an indictment of the literature, rather it is a reflection of TEC's unique characteristic - its intended complementarity to existing training systems.

A convenient way to place the training literature in perspective is to compare it with the TEC CTEA requirements identified above, and determine to what extent such requirements are addressed within the literature. While five TEC CTEA requirements are

mentioned, the first two (identification of the baseline and TEC-modified training systems) are problem specific, and cannot reasonably be expected to have been previously addressed. The third requirement is an input cost function, relating training activities (such as garrison training days, and specific types of field training days) to the total costs of carrying out those activities. While a number of documents reviewed nominally dealt with training cost estimation, their focus was on either very general procedures or actual cost estimation for specific hardware items. They appeared not to deal with the aggregate costs of the complete training system. For example, Kopstein and Seidel (1967), deals with estimating the costs of computer instruction, and both Walker (1974) and Shriver and Hart (1975) deal with general models of life cycle costing.[6]

The fourth identified TEC-CTEA requirement is an "effectiveness production function" which can relate any given levels of any types of training, along with other relevant variables, to a unit's (person's, platoon's, battalion's, etc.) combat effectiveness. This need for a production function relationship between training and effectiveness has widespread recognition (Braby, et. al., 1972; Braby, et. al., 1975; USATRADOC, 1975; Lukasczyk, 1976), yet apparently due to conceptual and practical difficulties, such a production function has yet to be constructed. That literature which has been identified herein as being associated with production functions (see abstracts) generally deals with the comparative characteristics of different production functions, but not with the estimation of effectiveness production functions. For example, the Proceedings of NTEC/Industry Conference (NTEC, 1975), contains several studies wherein the relative impacts of different types of training on individual effectiveness were examined. Such studies can be interpreted as casting light on the nature of certain partial derivatives of production functions, but do not address the nature of the whole function, nor the impacts on group effectiveness. A production function is estimated in Weiher and Horowitz, (1971), but this is not an effectiveness production function. Rather, it is a relation between the training inputs employed and the number of trained recruits produced.

The fifth requirement for a TEC CTEA is a transformation which can translate changes in effectiveness into corresponding dollar values. Such a transformation appears to be absent from the training literature. This absence has a simple explanation, however.

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[6] TEC-relevant cost estimating literature may be available in the future as a result of current research in the ODCSCOMP FORSCOM at Fort McPherson, Georgia.

Most new training programs which have undergone the scrutiny of an economic analysis (see abstracts dealing with efficiency and valuation issues) have been by nature, or have been analyzed as, substitute training programs. That is, the choice was between that program and some other. Both could not be chosen. In that context, it is meaningful to ask, if dollar resources are fixed, which program yields more effectiveness for the money; or if the effectiveness level is fixed, which program costs less to achieve that effectiveness level. Braby, et. al., 1972; Braby, et. al., 1975; Lukasczyk, 1976; and Toomepuu, 1977; are all studies which are examples of dealing with training programs as substitutes.

In sum, because of TEC's unique complementary role, it does not fit the usual training program mold, and analytical techniques currently available in the training literature are not completely suitable for a TEC evaluation. To be sure, general guidance for a TEC CTEA is available from documents such as the TRASANA CTEA Handbook, USATRADOC, 1975, and Braby, et. al., 1975. Nonetheless, it appears a TEC-specific evaluation methodology must be developed.

ECONOMIC LITERATURE

In contrast to the framework developed for training literature no such framework was deemed necessary for the economic evaluation literature.

This literature makes two general contributions to the development of a methodology for TEC evaluation. First, it provides a rational structure within which TEC evaluation can be carried out. While each author might emphasize somewhat different aspects of this structure, a single consistent and useful point of view, nonetheless, emerges. TEC should be evaluated using the so-called "with/without" approach[7] (Sassone and Shaffer, 1978; McKean, 1958; Dasgupta and Pearce, 1972; Eckstein, 1958; Hirshliefer, et. al., 1960; Krutilla and Eckstein, 1958; Little and Mirrlees, 1974) which involves the following steps:

- Definition of Problem

  This involves careful specification of the objectives, constraints, and the relevant society for which costs and benefits accrue.

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[7] "With/without" means comparing the state of affairs with the proposed project against the state of affairs without the project. This is in contrast to a "before/after" approach, for example.

- Identification of Alternative and Baseline Programs

  This is the specification of the programs or projects against which the proposed project is to be compared. As a minimum, the "status quo" is usually considered as the baseline for comparison

- Construction of Project Scenario

  A complete, quantitative and qualitative, and chronological description of resource inputs and outputs, and other economic/social ramifications of the proposed project, must be constructed

- Construction of Alternative (or Baseline) Scenarios

  A complete, quantitative and qualitative, and chronological description of the Alternative (or Baseline) Scenario must be constructed

- Identification of Differences Between Scenarios

  The differences between the Project and Alternative (or Baseline) scenarios must be recognized and physically quantified to the extent reasonable and possible

- Valuation of Differences

  Using market prices "shadow prices" (Dasgupta and Pearce, 1972; Sassone and Shaffer, 1978; Mishan, 1976; Sassone, 1977), the physical differences between scenarios should be valued in dollar terms to the extent reasonable and possible

- Aggregation over Time

  Using an appropriate discounting scheme, (Sassone and Shaffer, 1978; Mishan, 1976; Feldstein, 1964; Marglin, 1963 a; Marglin, 1963 b; Baumol, 1968), the valuations associated with different time periods must be aggregated into a sirgle "figure of merit"

- Sensitivity Analysis

  The sensitivity of the derived figure of merit to various assumptions and estimates should be examined

o Final Report

> The information generated by the analysis should be presented to relevant decision makers in an accessible and digestable format

By and large, the military training literature which addresses the structuring of a project evaluation is consistent with the spirit of the foregoing steps, although - as should be expected - the specific steps mentioned in that literature are tailored to specific military issues.

The second, and more important, contribution to the development of TEC evalution methodology made by the economics and cost-benefit literature is the suggestion of a way to place meaningful dollar values on changes in effectiveness wrought by changes in training. The approach involves the calculation of compensated and equivalent budget variations. Each author presents these concepts somewhat differently, and often cryptically (Currie, et. al., 1965; Samuelson, 1965; Mishan, 1976; Henderson 1941; Hicks, 1944; Dupuit, 1968; Hicks, 1956). The full flavor of these useful but highly technical concepts are conveyed in the development of the training evaluation model to be presented in a subsequent report.

SUMMARY AND CONCLUSIONS

This report is the first of a set of two reports dealing with CTEA methodology directed at the evaluation of the TEC program. This document reports on a review and evaluation of literature relevant to a TEC CTEA. The objective of the review is to identify State-of-the-Art methods and techniques applicable, in whole or part, to the performance of a TEC CTEA. The second document in this set describes the methodology formulated, in light of this review, to carry through a TEC CTEA. This present document can be viewed as background and introduction to that second document.

The TEC Program was designed as a series of multimedia, exportable, performance-oriented training packages. Its purpose is to provide high quality, uniform instruction in critical skills to individual and small groups of soldiers. A TEC CTEA must involve, like any CTEA, a comparison of the effectiveness and costs of alternative training systems. A CTEA must relate a (proposed or actual) change in the training system to its ultimate impact of combat effectiveness. There should be a clear "audit trail" from the former to the latter. In the case of TEC, a complementary training system focused on the individual soldier, establishing such an audit trail is likely to be a difficult undertaking. It involves tracing the impact of TEC through a number of "production function" relationships to some final impact on unit (not individual) combat effective-

ness. In a CTEA, the proposed alternative must be compared with the baseline system. The comparison can be of three different types: fixed cost, variable effectiveness; variable costs, fixed effectiveness; or variable costs, variable effectiveness. Because TEC is a complementary training system, its evaluation must be of the last variety. That is, because TEC is designed to be used with existing training systems, and not necessarily to replace any baseline training, TEC is intended to increase both costs and effectiveness. Its CTEA must, of course, reflect its designated objective and must determine whether the increase in effectiveness is worth the increase in costs.

Five methodological requirements for a TEC CTEA can be specified. These are:

- the baseline training system must be identified and its parameters quantified
- the training system inclusive of TEC must be defined and its parameters quantified
- an input cost function must be developed which maps any training system configuration into its dollar cost
- an effectiveness production function must be developed which maps any training system configuration into an objective measure of its effectiveness
- an approach must be devised which objectively translates changes in effectiveness into corresponding dollar values.

In order to determine whether any or all of these TEC CTEA methodological requirements could be satisfied from existing literature, a literature search was conducted. Two more or less separate bodies of literature were searched for TEC CTEA - relevant material. The first body was the training evaluation literature. This literature, comprised primarily of military documents, is problem oriented. It generally focuses on a specific training program. In contrast, the second body of literature was primarily theoretical in orientation. This was the economic evaluation literature, comprised of monographs and journal articles dealing with the general economic considerations of evaluating any type of program or project. Because of inherent differences between these two bodies of literature, different search procedures were used in each case to ferret out TEC - relevant material. For the training literature, computerized literature searches were employed to generate extensive lists of titles and abstracts. These were

screened on the basis of apparent TEC relevance, and those surviving the screening were reviewed in depth. The economic evaluation literature was selected from the subject classification indices of the Journal of Economics Literature, from the bibliographies of recent comprehensive monographs in project evaluation, and from among the well-known "classics" of the field.

A convenient framework providing a conceptual organization of the training literature was developed. It divides the training literature into four more or less mutually exclusive categories. These categories include literature dealing with the nature of effectiveness production functions (Class I), cost estimation issues (Class II), efficiency issues (Class III), and valuation issues (Class IV).

Methodology directly applicable to the evaluation of the TEC Program was not uncovered in the course of the survey of the training literature. However, a number of concepts and techniques which surfaced should prove useful as "building blocks" in the eventual constructing of a TEC CTEA methodology.

Training literature relevant to TEC Program evaluation can be expected to fall into Classes III and IV, primarily the latter. With regard to the Class III literature, it deals almost exclusively with Cost-Effectiveness issues. And as was pointed out, a TEC evaluation must be attacked on a Cost-Benefit basis. There are two reasons why the Class IV literature is not germane. One reason is that the literature deals with the "Substitute" subclass of Class IV, whereas TEC falls into the "Complement" subclass. Indeed, the sole military document in our Class IV deals with the "Substitute" case. However, the primary reason is that even the "Complement" literature deals with the evaluation of training programs in terms of the impact of the program on individuals' future earning potential. This is entirely appropriate for civilian training programs where the objective is either increased production[8] or increased income for the worker. However, insofar as military training programs - and the TEC Program in particular - have the objective of increasing combat effectiveness, and insofar as a soldier's mili-

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[8] In the private sector it can generally be assumed that an individual's wage is a measure of his productivity. Therefore, when an individual's marginal contribution to production cannot be directly estimated, his market determined wage is a useful surrogate. Thus, the effects of training on production can be inferred by studying changes in market wage rates.

tary wage cannot be presumed to measure his marginal contribution to combat effectiveness, the civilian literature would appear to have little bearing on TEC evaluation.

The major contribution of the training literature to a TEC evaluation is in the prescription of a general, rather than specific, course of analysis. Such documents as the TRASANA CTEA Handbook, USATRADOC, 1975, and Braby, et. al., 1975 present solid guidance regarding the philosophy. orientation, and direction of a TEC CTEA.

The economic evaluation literature makes two general contributions to the development of a methodology for TEC evaluation. First, it provides a rational structure within which a TEC evaluation can be carried out. This is the structure of cost- benefit analysis which a large number of authors have contributed to over the past several decades. Second, this literature suggests a way to place meaningful dollar values on changes in effectiveness brought about by changes in the training system. This approach involves the estimation of an effectiveness production function, and the calculation of compensating and/or equivalent budget variations.

The contributions of both the training and economic evaluation literatures to a TEC CTEA are general rather than specific. Both literatures provide useful outlines for constructing a TEC CTEA methodology, and the economic evaluation literature provides a means of translating effectiveness into a meaningful dollar equivalent. What remains to be developed are the all-important details. Specifically:

- o data availability for the estimation of the effectiveness production function must be established
- o efficient means of data collection must be devised
- o methods of data reduction/transformation to interface the data and the methodology must be developed
- o the best methods of statistical estimation under various conditions of data availability and quality must be identified
- o training cost estimation procedures must be developed
- o mathematical methods for the derivation of the compensated and equivalent budget variations for various functional specifications of the production function must be identified

- o reasonable methods of extrapolating the specific numerical results from TEC evaluation latitudinally (to MOSs other than those specifically dealt with) and longitudinally (to future years) must be developed

- o the best interpretations of alternative numerical results must be worked out

- o contingency methods to deal with data unavailability or other problems must be devised

These are some of the issues an ultimate TEC CTEA methodology must address.

BIBLIOGRAPHY

Arrow, K. J. An Extension of the Basic Theorems of Classical Welfare Economics, Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability. University of California Press, Berkeley: 1951.

Arrow, K. J. Social Choice and Individual Values. Wiley, New York: 1951.

Arrow, K. J. and Lind, R. C. Uncertainty and the Evaluation of Public Investment Decisions. American Economic Review, 1970.

Bator, F. M. The Anatomy of Market Failure. Quarterly Journal of Economics, 1958, 72, 351-379.

Bator, F. M. The Simple Analytics of Welfare Maximization. American Economic Review (Vol. 47). March, 1957.

Baumol, W. J. On the Social Rate of Discount. American Economic Review, 1968, 58, 788-802.

Baumol, W. J. Urban Services: Interactions of Public and Private Decisions. Public Expenditure Decisions in the Urban Community, Howard G. Schaller, ed., Resources for the Future, Inc., Washington: 1963.

Baumol, W. J. Welfare Economics and the Theory of the State. Harvard University Press, Cambridge, Massachusetts: 1965.

Braby, R., Micheli, G., Morris, C. L. and Okraski, H. C. Staff Study on Cost and Training Effectiveness of Proposed Training Systems (Report No: TAEG - 1). Naval Training Equipment Center, Orlando, Florida: Training Analysis and Evaluation Group, 1972.

Braby, R., Henry, J. M., Parrish, W. F. and Swope, W. M. A Technique for Choosing Cost-Effective Instructional Delivery Systems (Report No: TAEG - 16). Naval Training Equipment Center, Orlando, Florida: Training Analysis and Evaluation Group, 1975.

Buchanan, J. M. and Stubblebine, W. C. Externality. Economica, N. S. (Vol. 29). November, 1962.

Buchanan, J. M. and Tullock, G. The Calculus of Consent. University of Michigan Press, Ann Arbor: 1962.

Byrne, A. and Duren, D. R. Advanced Technical Data Study, Phase III - Test Plan. Boeing Aerospace Company, Seattle, Wash.: 1974. (AD-B001 675/8ST)

Coase, R. H. The Problem of Social Cost. The Journal of Law and Economics (Vol. 3). October, 1960.

Currie, J. M., Murphy, J. S. and Schmitz, A. The Concept of Economic Surplus and Its Use in Economic Analysis. The Economic Journal, December, 1965.

Dasgupta, A. K. and Pearce, D. W. Cost-Benefit Analysis. Barnes and Noble, New York: 1972.

Dasgupta, P., Marglin, S. and Sen, A. Guidelines for Project Evaluation. United Nations, 1972.

Davis, O. A. and Whinston, A. Externalities. Welfare, and the Theory of Games. Journal of Political Economy (Vol. 70). June, 1962.

Debreu, G. Theory of Value. Wiley, New York: 1959.

Demonstration and Evaluation of the PLATO IV Computer-Based Education System. (Computer-Based Education for a Volunteer Armed Service Personnel Program). Illinios University at Urbana-Champaign Computer-Based Education Research Lab: Dec., 1975. (AD - A024 824/5ST)

Demonstration and Evaluation of the PLATO IV Computer-Based Education System. (Computer-Based Education for a Volunteer Armed Service Personnel Program). Illinios University at Urbana-Champaign Computer-Based Education Research Lab: Advanced Research Projects Agency, Arlington, Virginia: June, 1975. (AD - A017 399/7ST)

Dorfman, R., ed. Measuring Benefits of Government Investments. The Brookings Institute, Washington, D. C.: 1965.

Downs, A. An Economic Theory of Democracy. Harper, New York: 1957.

Dupuit, J. On the Measurement of the Utility of Public Works. Annales des Ponts et Chaussees, Second Series (Vol. 8), 1844. Translation reprinted in D. Munby, Transport, 1968.

Eckstein, O. Investment Criteria for Economic Development and the Theory of Intertemporal Welfare Economics. Quarterly Journal of Economics, 1957, 71, 56-85.

Eckstein, O. Water Resources Development: The Economics of Project Evaluation. Harvard University Press, Cambridge, Massachusetts: 1958.

Economics of Public Finance, The. The Brookings Institute, Washington, D. C.: 1974.

Feldstein, M. Net Social Benefit Calculation and the Public Investment Decision. Oxford Economic Papers, 1964.

Gay, R. M. and Nelson, G. R. Cost and Efficiency in Military Specialty Training. Rand Corporation, Santa Monica, California: January, 1974. (AD-786 652/8ST)

Goldfarb, R. S. The Evaluation of Government Programs: The Case of New Haven's Manpower Training Activities. Yale University, New Haven, Connecticut: 1968. (PB-182 173)

Graaff, J. de V. Theoretical Welfare Economics. Cambridge University Press, Cambridge, England: 1957.

Haveman, R. H. and Krutilla, J. V. Unemployment, Idle Capacity, and the Evaluation of Public Expenditure. Resources for the Future, Inc., Washington, D. C.: 1968.

Henderson, A. Consumer's Surplus and the Compensating Variation. Review of Economic Studies, 1941.

Henderson, J. M. and Quandt, R. E. Microeconomic Theory. McGraw-Hill, New York: 1971.

Hicks, J. R. Foundations of Welfare Economics. Economic Journal (Vol. XLIX). December, 1939.

Hicks, J. R. The Rehabilitation of Consumers' Surplus. Review of Economic Studies (Vol. 8). February, 1940-41.

Hicks, J. R. The Four Consumers' Surpluses. Review of Economic Studies (Vol. 11). Winter, 1943.

Hicks, J. R. The Four Consumers' Surpluses. Review of Economic Studies, 1944.

Hicks, J. R. Value and Capital. Clarendon Press, Oxford: 1939.

Hicks, J. R. Value and Capital: An Inquiry Into Some Fundamental Principles of Economic Theory (2nd ed.), Oxford: 1946.

Hicks, J. R. The Generalized Theory of Consumer's Surplus. Review of Economic Studies (Vol. 13). 1945-46.

Hicks, J. R. Consumers' Surplus and Index Numbers. Review of Economic Studies (Vol. 9). Summer, 1942.

Hicks, J. R. A Revision of Demand Theory. London: 1956.

Hirshliefer, J. Theory of Optimal Investment Decision. Journal of Political Economy, 1958.

Hirshliefer, J., DeHaven, J. C. and Milliman, J. W. Water Supply: Economics, Technology and Policy. University of Chicago Press, Chicago: 1960.

Hitch, C. J. and McKean, R. N. Economics of Defense in the Nuclear Age. Harvard University Press, Cambridge, Massachusetts: 1960.

Hitch, C. J. and McKean, R. N. Suboptimization in Operations Problems Operations Research for Management. J. F. McCloskey and J. F. N. Trefethen, eds., Johns Hopkins University Press, Baltimore: 1954.

Intriligator, M. D. Mathematical Optimization and Economic Theory. Prentice-Hall, Englewood Cliffs, New Jersey: 1971.

Kaldor, N. Welfare Propositions in Economics. Economic Journal (Vol. XLIX). September, 1939.

Koopmans, T. C. Analysis of Production as an Efficient Combination of Activities. Activity Analysis of Production and Allocation, T. C. Koopmans, ed. Wiley, New York: 1951.

Koopmans, T. C. Three Essays on the State of Economic Science. McGraw-Hill, New York: 1957.

Kopstein, F. F. and Seidel, R. J. Computer-Administered Instruction Versus Traditionally Administered Instruction: Economics. George Washington University Human Resources Research Office: Alexandria, Virginia: June, 1967. (AD-656 613)

Kribs, H. D. Computer-Based Instruction for TRIDENT F8M Training. Navy Personnel Research and Development Center, San Diego, California: June, 1976. (AD-A041 162/9ST)

Krutilla, J. V. and Eckstein, O. Multiple Purpose River Development. Johns Hopkins University Press, Balitmore: 1958.

Lesourne, J. Cost-Benefit Analysis and Economic Theory. North Holland Publishing Company, Holland: 1975.

Little, I. M. D. A Critique of Welfare Economics, 2nd ed., Oxford University Press, London and New York: 1957.

Little, I. M. D. A Critique of Welfare Economics. Oxford: 1960.

Little, I. M. D. and Mirrlees, J. A. Project Appraisal and Planning for Developing Countries. Basic Books, New York: 1974.

Litton Systems, Inc./Mellonics Systems Development Division. Task Report - Training Extension Courses - Development of a TEC Manager's Guide. January, 1978.

Lukasczyk, N. Efficiency Indicators for Education and Training. Naval Postgraduate School, Monterey, California: June, 1976. (AD-A028 854/8ST)

Maass, A. Benefit-Cost Analysis: Its Relevance to Public Investment Decisions. Quarterly Journal of Economics, May, 1966, 80, 208-226.

Marglin, S. A. Public Investment Criteria. London: 1967.

Marglin, S. A. The Opportunity Costs of Public Investment. Quarterly Journal of Economics. 1963 (a).

Marglin, S. A. The Social Rate of Discount and the Optimal Rate of Investment. Quarterly Journal of Economics. 1963 (b).

McKean, R. N. Efficiency in Government through Systems Analysis. Wiley, New York: 1958.

McKean, R. N. Issues in Defense Economics. Columbia University Press, New York: 1967.

McKean, R. N. Public Spending. McGraw-Hill, New York: 1968.

Meade, J. E. External Economies and Diseconomies in a Competitive Situation. Economic Journal (Vol. 62). March 1952.

Mishan, E. J. A Survey of Welfare Economics. Economic Journal (Vol. 70). June, 1960.

Mishan, E. J. Cost-Benefit Analysis. Praeger Publishers, New York: 1976.

Mishan, E. J. The Recent Debate on Welfare Criteria. Oxford Economic Papers. 1965.

Mishan, E. J. Welfare Criteria: Are Compensation Tests Necessary? Economic Journal (Vol. LXXIII). June, 1963.

Mishan, E. J. Welfare Econmics: An Assessment. North Holland Publishing Company, Amsterdam: 1969.

Mishan, E. J. What is Producer's Surplus? American Economic Review (Vol. 58). December, 1968.

Montemerlo, M. D. and Tennyson, M. E. Instructional Systems Development: Conceptual Analysis and Comprehensive Bibliography. Naval Training Equipment Center, Orlando, Florida: February, 1976 (AD-A024 526/6ST)

Olson, M., Jr. The Logic of Collective Action. Harvard University Press, Cambridge, Massachusetts: 1965.

Pigou, A. C. The Economics of Welfare. (4th edn.) Macmillan, London: 1932.

Pigou, A. C. The Economics of Welfare. (4th edn.) Macmillan, London: 1946.

Prest, A. R. and Turvey, R. Cost-Benefit Analysis: A Survey. The Economic Journal. December, 1965.

Proceedings of NTEC/Industry Conference (8th): New Concepts for Training Systems Held on 18-20 November 1975. Naval Training Equipment Center, Orlando, Florida. (AD-A028 885/2ST)

Proceedings of the Annual Naval Training Device Center and Industry Conference (4th) Held at Orlando, Florida, on 18-20 November, 1969. Naval Training Device Center, Orlando, Florida. (AD-707 757)

Rizzo, W. A. Demonstration and Evaluation of a Microfiche-Based Audio/Visual System. Focus on the Trained Man. Training Analysis and Evaluation Group (Navy) Orlando, Florida: April, 1977.

Roscoe, S. N. Incremental Transfer Effectiveness. Illinois University Savoy Aviation Research Laboratory. 1971. (AD-749 121 and AD-748 235)

Rothenberg, J. The Measurement of Social Welfare. Prentice Hall, New Jersey: 1961.

Samuelson, P. A. Foundations of Economic Analysis. Atheneum, New York: 1965. (originally published by Harvard University Press, 1945).

Sassone, P. G. and Shaffer, W. A. Cost-Benefit Analysis: A Handbook. Academic Press, New York: 1978.

Sassone, P. G. Shadow Pricing in CBA: Mathematical Programming and Economic Theory. The Engineering Economist (Vol. 22, No. 3). Spring, 1977.

Scitovsky, T. A Note on Welfare Propositions in Economics. Review of Economic Studies. 1941.

Scitovsky, T. Two Concepts of External Economies. Journal of Political Economy (Vol. 52). April, 1954.

Shriver, E. L. and Hart, F. L. Study and Proposal for the Improvement of Military Technical Information Transfer Methods. Kinton, Inc. Alexandria, Virginia: December, 1975. (AD-A023 409/6ST)

Spangenberg, R. W., Riback, Y. and Moon, H. L. The State of Knowledge Pertaining to Selection of Cost-Effective Training Methods and Media. Human Resources Research Organization, Alexandria, Virginia: June, 1973. (AD-763 194)

Steiner, P. O. Choosing Among Alternative Public Investments in the Water Resource Field. American Economic Review, 1959, 49, 893-916.

Strasel, H. C., et. al. Training Extension Courses (TEC) Costs and Training Effectiveness, U. S. Army Research Institute for the Behavioral and Social Sciences, Research Report Draft (Unclassified): November, 1977.

Takayama, A. Mathematical Economics. Dryden, Hinsdale, Illinios: 1974.

Toomepuu, J. Army Flight Simulator Programs from the User's Viewpoint. Army Training Support Center, Fort Eustis, Virginia: May, 1976. (AD-A029 266/4ST)

Toomepuu, J. Test and Evaluation of the Army's CH-47 Helicopter Flight Simulator. Army Training Support Center, Fort Eustis, Virginia: January, 1977. (AD A036 159/2ST)

Unco, Inc. Methodology for Measuring Cost-Effectiveness of Manpower Programs: Development and Application. Washington, D. C.: August, 1973. (PB-226 862/1)

U. S. Army Aviation Center, Fort Rucker, Alabama. Cost and Training Effectiveness Analysis (CTEA) of the CH-47 Flight Simulator. December, 1976. (AD-A033 972/1ST)

U. S. Army Training and Doctrine Command (TRADOC). Analyzing Training Effectiveness. (TRADOC PAM 71-8) Fort Monroe, Virginia: Author, 1975.

U. S. Army TRADOC Systems Analysis Activity. Cost and Training Effectiveness Analysis (CTEA) Handbook. White Sands Missile Range, New Mexico: Author, 1976.

Vecchiotti, R. A. A Survey and Analysis of Military Computer-Based Training Systems: (A Two Part Study). Volume II. A Descriptive and Predictive Model for Evaluating Instructional Systems. McDonnell Douglas Astronautics Co-East, St. Louis, Missouri: May, 1977. (AD-A043 358/1ST)

Walker, G. A. Life Cycle Cost/System Effectiveness Evaluation and Criteria. Boeing Company, Seattle, Washington: January, 1974. (AD-916 001/1ST)

Weiher, R. and Horowitz, S. A. A Production Function for Trained Recruits. Center for Naval Analyses. Arlington, Virginia: November, 1971. (AD-734 858)

Whinston, A. Price Coordination in Decentralized Systems. (doctoral dissertation), Carnegie Institute of Technology: June, 1962.

ADDENDA

Barsby, S. L. Cost Benefit Analysis and Manpower Programs. Lexington Books, Lexington, Massachusetts: 1972.

Harberger, A. C., et. al. (eds.) Benefit Cost Analysis 1971. Aldine-Atherton, Chicago: 1972.

Haveman, R. H., et. al. (eds.) Benefit-Cost and Policy Analysis. Aldine Publishing Company, Chicago: 1974.

U. S. Army TRADOC Systems Analysis Activity. B-33 Cost and Training Effectiveness Analysis Report, TRASANA 15-77 (Unclassified) White Sands Missile Range, New Mexico: Author, June, 1977.

APPENDIX - ABSTRACTS

ABSTRACTS

This appendix provides synopses of recent literature relevant to TEC evaluation. The synopses are presented in two groups: one of Training Literature and one of Economic Literature.

TRAINING LITERATURE

Computerized literature searches were employed to identify that training literature relevant to the development of a TEC CTEA methodology. Two searches of the National Technical Information Service (NTIS) data base were conducted, which resulted in an extensive list of titles and abstracts all with at least some tangential relevant training evaluation. The abstracts were reviewed, and a set of approximately 40 documents apparently relevant to a TEC CTEA was identified. These documents were reviewed in detail and, on a basis of actual TEC CTEA relevance, a subset of that set are abstracted herein.

The training literature is arranged according to the Issue Classification Framework developed in the text (pp. 7-11). Needless to say, few reports, articles or books fit perfectly into a single class. Of necessity, a certain amount of judgement must be exercised in the classification process. Where a piece of literature deals in a substantial way with more than one issue, it is classified according to its primary thrust, but its treatment of other issues is noted by brackets after the title. Within the brackets are noted the other classes in which that piece of literature might reasonably be catalogued.

The reader will doubtless note that much of the training literature surveyed here falls into our Class III. This is no accident. While our primary interest is in the class in which TEC evaluation would fall, namely Class IV, that class happens to be extremely sparsely populated. Literature most closely related to Class IV is in Class III, and that set, being reasonably abundant, is therefore accorded a substantial representation.

Literature Dealing with Production Function Issues. Weiher, R. and Horowitz, S. A. A Production Function for Trained Recruits. Center for Naval Analyses. Arlington, Virginia: November, 1971. The purpose of this study was to determine the output capability, or capacity, of the Navy's initial entry training bases under (then) current and alternative operating policies, as well as under various

output requirements associated with alternative force levels. This is accomplished by estimating: 1) the feasible output of trainees that can be obtained with the resources currently at the recruit training bases; 2) the "surge" capability of the bases if extra instructors are assigned to the recruit training commands; and 3) the capacity of the recruit training establishment for any combination of facilities and instructors at the bases. The paper also examines the question of scale economies in recruit training. The analysis centers around a production function where the number of trained recruits is assumed to be a function of the value of the physical training facilities, the input labor (instructor time), and the number of input recruits. Using annual data for the years 1964-1969, the production function was estimated using a least squares technique. Among the conclusions are that Navy training exhibits constant returns to scale, that excess recruit training capacity existed in 1970, and that savings might be induced if recruit loads were distributed differently among the training bases.

Proceedings of the 8th NTEC/Industry Conference: New Concepts for Training Systems (18-20 November 1975), Naval Training Equipment Center Technical Report IH-275 (Unclassified), November 1975, (AD A028 885). The conference was intended to provide the environment for the exchange of ideas and concepts in training systems. Several papers are mentioned here.

- Evaluation of an Automated Flight Training System (Puig, J. A. and Gill, S.). This paper investigated whether training with the automated GCA module was as effective as conventional training. An experimental group and a control group were used. In each case, training was to proficiency and the automatic performance measurement capabilities of GCA were used, in addition to the instructor scoring. A questionnaire concerning the effectiveness of training with the GCA module (involving instructors and students) was another evaluation device. The results indicated that training with the GCA module was as effective, and perhaps more effective, than conventional training.

- USAF Evaluation of an Automated Adaptive Flight Training System (Brown, J. E., et. al.). The major objectives of the reported research were:

  - o to evaluate the training effectiveness of the Automated Flight Training System (AFTS) in the F-4 Training Program
  - o to identify desired hardware and software modifications for operational devices
  - o to identify effective methods of operational training use.

One of the major characteristics of the AFTS was its use of adaptive training. An experimental and control group were used. Performance under the experienced GCA controllers was assumed to represent the major criterion for evaluating the training effectiveness of the AFTS system. The results of the evaluation indicated the AFTS to be an effective system for training GCA's. The cost-effectiveness of the system was not determined, however.

• An Evaluation of Computer Based Instruction for Performance of "Hands-On" Training Evolutions (Radsken, J. W. and Grosson, J. F.). This paper describes an evaluation conducted at the Guided Missile School, Dam Neck, Virginia where three different computer based systems were used to compare computer based instruction (CBI) with conventional instruction. The objective was to ascertain if certain "hands-on" training evolutions could be performed on computer systems and thus reduce requirements for tactical training equipment. A test group and a control group were used. The parameters of training effectiveness were time to train and level of knowledge and skill capability. Cost aspects were not discussed in the paper. It was concluded that CBI is a feasible approach for reducing tactical hardware utilization for interactive operator training and basic maintenance training tasks. When compared to conventional instruction, CBI provides comparable capability in knowledge and skill as well as in time to train.

Demonstration and Evaluation of the Plato IV Computer-Based Education System; Advanced Research Projects Agency; ARPA Order No. 2245 (Unclassified), December 1975, (AD A024 824) [Secondary Classification: III]. This semi-annual report describes a program aimed at demonstration, testing, and evaluation of the educational effectiveness of Plato as implemented in several geographically dispersed military training sites. It also describes a program of technical modifications aimed at increasing the effectiveness of the Plato system. It summarizes the highlights and major events of the ARPA/PLATO project for the second half of 1975.

Strasel, H. C., et. al. Training Extension Courses (TEC) Costs and Training Effectiveness, U. S. Army Research Institute for the Behavioral and Social Sciences, Research Report Draft (Unclassified), November 1977 [Secondary Classification: III]. The report summarizes a series of research efforts on the Training Extension Course (TEC) program conducted under the sponsorship of the U. S. Army Training Support Center - Training Programs Directorate. This program included detailed research into the training effectiveness of TEC, the current and programmed costs of the TEC program, current and projected usage of TEC in the Active and

Reserve components, and analytic examination of the cost effectiveness of TEC. The analyses and results are presented in relation to a series of seven questions about TEC posed by Department of the Army Staff. The research used several approaches to answer these questions, including both analytical and empirical approaches. The empirical approaches included:

- o an experimental study of the effectiveness of TEC training and the retention of learning with TEC in comparison to conventional training and no training, for both Active and Reserve Components
- o a survey of TEC usage and the attitudes and problems expressed by TEC users, non-users, training officers and NCOs, and Training Support personnel, in CONUS and USAREUR Active units and Reserve units
- o an analysis of the relationship of TEC lesson usage and SQT performance in six battalions in CONUS
- o collection of all identifiable costs related to previous TEC program and projected costs on a uniform annual cost basis for the next ten years.
- o collection from TRADOC Schools of ways TEC has been used to supplement or substitute for conventional training and the cost savings therefrom

Using these and other data, a series of analyses were performed to determine the potential and real cost effectiveness of TEC training for the U. S. Army.

The report concludes that TEC is both cost and training effective at the current levels of training effectiveness and the current level of usage. Analyses further indicate that, if TEC usage is raised through command emphasis and development of better methods and strategies for TEC implementation, the cost and training effectiveness of TEC will be greatly increased. Current research and development efforts to speed the better implementation of TEC must be continued to realize these increases.

Literature Dealing with Cost Estimation Issues. Kopstein, F. F. and Seidel, R. J. Computer-Administered Instruction Versus Traditionally Administered Instruction: Economics, George Washington University's Human Resources Research Office, Professional Paper 31-67 (Unclassified), June 1967, (AD 656 613). A cost comparison of computer-administered instruction (CAI) versus traditionally-administered instruction (TAI) is made in this report based on an assumption of equal effectiveness for TAI and CAI. The mean cost

per student hour is used as a base line. TAI costs are divided into three categories: public elementary and secondary education, higher education, and military training. Cost figures are obtained for each of these categories. CAI categories are hardware, maintenance and spare parts, software, and instructional design and program preparation. CAI costs per student per hour are the total costs in these categories during operating life distributed over the total number of students who make use of the system during each one of its life hours. Costs are obtained for each category. An economic comparison is then made of CAI and TAI costs. The report concludes that CAI is more expensive than TAI in public education, but is more competitive in higher education and military training. Among the educational (in contrast to economic) considerations discussed are that CAI can potentially adapt the instructional presentation not only to the detailed characteristics of the trainee, but also to his precise requirements of the moment.

The future of CAI and TAI is also discussed. Given a number of assumptions, it is predicted that in less than 10 years, CAI costs will be roughly half the cost of comparable TAI.

Walker, G. A. Life Cycle Cost/System Effectiveness Evaluation and Criteria. The Boeing Company, Document No. D180-17648-1 (Unclassified), January 1974, (AD 916 001). This report contains the results of an independent research and development task on life cycle cost performed by Boeing Aerospace Company. Due to the growth of weapon acquisition and support costs, a need is recognized for a cost analysis technique that is simple, flexible, low cost, and easily applied throughout early phases of a program. Literature on life cycle cost technology was reviewed and organized. The conclusions were that no LCC model had been successfully applied to perform total LCC trade-off studies on a major on-going program, and that a practical method for determining LCC does not yet exist. Also, the report notes that no attempt has been made to develop a standard tool, or technique, for determining "systems worth". Recommendations are offered for improving methods of effectively performing LCC analysis on new design programs.

A discussion follows on program life cycle phases; how cost analysis applies to each of these phases; how models/analysis techniques should be selected; functional elements to be considered; and general documentation pertaining to the research project.

Shriver, E. L. and Hart, F. L. Study and Proposal for the Improvement of Military Technical Information Transfer Methods. U. S. Army Human Engineering Laboratory, Technical Memorandum 29-75 (Unclassified), December 1975, (AD A023 409). The study proceeds from the observation that the cost of owning equipment is

more than the cost of procuring it. The objective of the study was to develop a more cost effective equipment maintenance program. It reviewed new concepts for technical manuals which have been developed and tested over the past twenty years. The processes and techniques used by these concepts are identified, analyzed, and summarized in a specification incorporating the best features of each. The improved maintenance program developed by this study could result in lower maintenance costs, better reliability, and higher availability of Army material.

The report is organized into seven tasks:

Task 1: To identify new concepts for maintenance that hold promise for reducing the cost of equipment ownership.

Task 2: To analyze the new concepts in order to identify the fundamental elements responsible for their effect upon maintenance cost.

Task 3: To match fundamental elements to particular Army situations, to evaluate their validity, and to make broad cost projections.

Task 4: To review the fundamental elements against the Commodity Systems, and project the cost of ownership which could accrue through use of these elements to produce all Army TMs.

Task 5: To prepare a specification which includes all the fundamental elements tailored to Army situations where they are appropriate.

Task 6: Prepare a sample manual based on the specification.

Task 7: Prepare a test plan for testing the sample material.

Instead of using training to provide the new maintenance personnel with general information which is combined with specific equipment descriptions on the job, the recommended approach is to analyze all jobs and describe exactly what is to be done in the TM to maintain the equipment.

Literature Dealing with Efficiency Issues. Roscoe, S. N. Incremental Transfer Effectiveness, Aviation Research Laboratory at University of Illinois, Technical Report ARL-70-5/AFOSR-70-1 (Unclassified), February 1971, (AD 748 235) and Roscoe, S. N. Incremental Transfer Effectiveness, Human Factors, 1971, 13(6), pp. 561-567, (AD 749 121). These two reports present a method for measuring transfer of learning. They deal with a method for deter-

mining when to substitute one type of training for another based on the incremental time saved and cost incurred.

A universal relationship is postulated in which the effectiveness of successive increments of training on one task, as measured by the relative incremental savings in learning a second task, is a negatively decelerated function of the time devoted to pretraining or interpolated training on the former task. It is further postulated that the relationship, inferred from aircraft-pilot training situations, applies in different forms to all educational experiences, thereby allowing all formal educational programs, in theory, to be evaluated in terms of their incremental cost effectiveness.

Braby, R., et. al. Staff Study on Cost and Training Effectiveness of Proposed Training Systems, Training Analysis and Evaluation Group (TAEG) at Naval Training Equipment Center, TAEG Report 1 (Unclassified), 1972. This report discusses the results of a staff study to develop a procedure for evaluating alternate training systems and for selecting among them the most cost effective ones. A prototype Training Effectiveness and Cost Effectiveness Prediction Model (TECEP) was developed and tested. This is a method for the optimization of training media allocation on the basis of fixed training effectiveness and minimum cost. The overall model consists of three sub-models: media substitution and selection, life cycle cost, and optimization. Media alternatives are identified through the use of a media selection matrix. Media costs are developed through the use of life cycle cost analysis (categorization of cost factors, estimation of cost factor values, and calculation of cost per utilization hour for each medium). Linear programming is used as an optimizing tool for determining least cost training media. Application of the TECEP Model is made to the TA-4 Aircraft Training System as a demonstration of the feasibility of the model.

Spangenberg, R. W., et. al. The State of Knowledge Pertaining to Selection of Cost-Effective Training Methods and Media. Human Resources Research Organization, Technical Report 73-13 (Unclassified), June 1973, (AD 763194). In order to prepare a plan for research toward empirical determination of criteria and procedures for optimal selection of cost-effective methods and media, a review and analysis of pertinent literature was conducted. The research fell into two major categories:

- those pertaining to methods-media definition and classification, and methods-media selection criteria and procedures

- o those pertaining to training cost-effectiveness and analytical procedures.

The authors reported that the empirical data found on the relative cost-effectiveness of methods and media were insufficient as a basis for reliable selection of methods and media for specific training tasks. Also, the existing methods-media selection procedures, training cost-analysis procedures, and suggested approaches for developing such procedures were inadequate for Army needs, although portions of some existing procedures may be useful in developing new procedures for Army use. Most selection procedures developed outside the Army were designed for use in civilian schools, and others were based upon specific restrictive assumptions and theories that do not sufficiently apply to Army conditions. They found that existing selection procedures used in civilian schools have proved to be unsuccessful even for their intended purposes (selection criteria used were too general). New approaches to methods-media problems are also discussed.

Braby, R., et. al. A Technique for Choosing Cost-Effective Instructional Delivery Systems, Training Analysis and Evaluation Group at Naval Training Equipment Center, TAEG Report No. 16 (Unclassified), April 1975. The purpose of this report is to make available to training specialists a procedure for choosing instructional delivery systems appropriate to various types of military training. The procedure is the Training Effectiveness, Cost Effectiveness Prediction (TECEP) technique. It is intended to provide an orderly approach for the skilled training system designer to use in making delivery system choices during the conceptual design phase.

A three-step procedure is described in which training objectives are classified and organized into groups, media capable of supporting these strategies are identified, and the costs of alternative forms of training are projected. Using such information, it is contended that optimum delivery system choices can be made.

The TECEP technique is viewed as a single part of larger Training System Development Model. The technique is not mechanical and does require user expertise. It is best described as a job aid for an experienced training system designer. The report suggests that it can provide a pathway and procedures for systematically coming to grips with critical issues in planning cost-effective instruction.

Analyzing Training Effectiveness, Headquarters U. S. Army Training and Doctrine Command, TRADOC PAM 71-8 (Unclassified), December, 1975. This document is primarily didactic. It describes

methods used by TRADOC to point the way toward increased effectiveness for selected combat material through improved training. The methods discussed include problem formulation, model construction, and model testing; as well as illustrations of model use. The first chapter discusses the motivation, need, and payoff for improved training. The second chapter summarizes a number of useful operations research (OR) models, including a general effectiveness model, learning curves, readiness models, and simulation models. Analytical tools and procedures are discussed in the next chapter. Tools include systems analysis and task analysis; procedures include the Train Up Study (TUS), the CTEA, and the Training Input To COEA study. The final chapter identifies several of the major funding, research, testing and analytic resources that are available to support training effectiveness analysis. Programs discussed include the Concept Evaluation Program (CEP), the Human Resources Research Program (HRRP), and the TRADOC Study Program (TSP). Various test organizations are profiled, as is TRASANA.

Toomepuu, J. Army Flight Simulator Programs from the User's Viewpoint. U. S. Army Training Support Center. (Unclassified), May 1976, (AD A029 266). The report discusses problems and desirable directions in training effectiveness analysis. It covers three topics:

- o user evaluation of the quality and suitability of the Army flight simulator program
- o cost effectiveness of flight simulators
- o research initiatives needed to meet Army aviation training needs.

The author contends that while operational testing is the primary means for user evaluation, some evaluation is needed before this point is reached. User participation should be provided for all stages of the research program. Causes for lack of user participation, as well as suggestions for user participation, are discussed.

Regarding the effectiveness measurement of simulators, the author argues that a methodology is needed that is based on task analysis, identifies the cues required by pilots to perform these tasks, and matches cue elements with the elements of the simulator subsystems that provide the cues. A training cost allocation methodology also needs to be developed to adequately measure both alternative training system costs and simulator training costs, and the contribution to the overall cost by simulator subsystems and their elements. Simulators should be justified on the basis of all relevant cost-effectiveness considerations.

Research initiatives in the area of flight simulators and their users are proposed in the context of future aircraft and organizations, operational doctrine and tactics, and management of aviation training assets.

Lukasczyk, N. Efficiency Indicators for Education and Training. Naval Postgraduate School, Master's Thesis (Unclassified), June 1976, (AD A028 854). The purpose of this report is to propose and analyze indicators of education and training efficiency for the Chief of Naval Education and Training (CNET). The indicators should measure how effectively CNET is producing a given output in a given time period relative to previous time periods. Three indicators are discussed: the Staff/Student Ratio, Cost per Student per Unit Time, and Cost per Graduate.

The arguments contend that the cost per graduate is the most appropriate indicator for a single course. Procedures are derived for the appropriate aggregation of multiple courses. The derived indicators have the mathematical form of the Laspeyres and Paasch indicators, used in economic theory for the cost of living index. They are applied to sixty courses of SSC San Diego and compared to indicators determined by linear regression based on the same data set. The resulting values of the indicators are believed to be helpful to locate the area of interest and detail for further decision making.

Cost and Training Effectiveness Analysis (CTEA) of the CH-47 Flight Simulator (CH47FS), CH47FS Study Group at U. S. Army Aviation Center, ACN 23879 (Unclassified), December 1976, (AD A033 972) and Toomepuu, J. Test and Evaluation of the Army's CH-47 Helicopter Flight Simulator, U. S. Army Training Support Center, (Unclassified), January 1977, (AD A036 159). Both reports concern the determination of the cost and training effectiveness of the CH-47 Flight Simulator when utilized in the CH-47 Aviator Qualification Course and CH-47 aviator unit training.

The objectives were to:

- o determine the training effectiveness of each alternate training package
- o estimate the pertinent costs of each alternate training package
- o determine the cost and training effectiveness of each alternate training package
- o rank order the alternate training packages on the basis of appropriate quantitative cost and training

effectiveness measures, and judgmental evaluations of the situations in which the alternates are expected to be used.

- o prepare a recommended CH47FS basis-of-issue plan for the preferred packages
- o ascertain the impact each alternate training package will have upon Army-wide combat readiness of Army's CH-47 assets.

The scope of the study was to:

- o address the cost and training effectiveness of the alternate training packages, considering anticipated resource constraints, combat readiness of the Army's CH-47 assets, and safety
- o include a review of the Synthetic Flight Training System Training Device Requirement
- o recommend a basis-of-issue plan for the CH47FS.

The methodology includes variable cost/fixed effectiveness analysis and judgmental evaluations, effectiveness analysis, and cost analysis. Measures of training effectiveness used were aviator performance evaluation scores and training hour necessary to attain specific performance objectives. The life cycle cost estimate was determined in terms of training cost per aviator for each alternate, and total cost for each alternate.

A Survey and Analysis of Military Computer-Based Training Systems: (A Two-Part Study) Volume II, McDonnell Douglas Astronautics Company - East, MDC E1570 (Unclassified), May 1977, (AD A043 358). The purpose of this report was to develop a means for assessing the cost versus expected benefits of innovations in computer-based training systems. A three pronged approach was used to address the problem. First, a descriptive model of a generalized, computer-based training system was developed. Second, a predictive model was generated to describe student performance in a computer-based training environment. Third, a computer program incorporating the predictive model was developed to estimate the cost of implementing one particular training innovation, i. e., revision of a conventional instructional program into a self-paced instructional program. A linear prediction model was developed to predict the time required for a student to complete a unit of self-paced instruction thereby demonstrating

the time saved by converting from a conventional instructional mode. This was combined with the Rand Corporation's MODIA cost analysis program. The study demonstrated that a viable time savings and cost model can be developed given a sufficient data base from which to draw the necessary course content and student characteristics descriptions. The generality and precision of such a model is dependent on the breadth and accuracy of the data base from which the model is derived. Although the data base employed in this study was not as complete as could be desired, the resultant model was found to be reasonably accurate and is sufficiently general to be of value in the evaluation of courses for individualization. Thus, a methodology was developed and demonstrated which can become a useful tool as additional data are accumulated from computer-based training systems.

B-33 Cost and Training Effectiveness Analysis Report, U. S. Army TRADOC Systems Analysis Activity, TRASANA 15-77 (Unclassified), June, 1977. This report concerns the cost and training effectiveness of the Swedish SAAB-SCANIA BT-33 simulator (for training forward observers) as compared to current methods of training (field and live fire exercises). The objectives of the analysis are to determine the effectiveness of the BT-33 to train forward observers in:

- o preparation of the call for fire
- o target location
- o fire adjustment

In addition, it was to determine the relative costs of three different combinations of BT-33 simulation and conventional forward observer training. The methodology consisted of defining alternatives, making explicit assumptions, and determining the costs for each alternative. Sensitivity of alternative cost rankings was then conducted.

The report concludes that the BT-33 proved to be an effective training device to complement classroom training. It appeared to offer significant savings compared to conventional live fire training methods; however, it results in increased costs if used only for conventional classroom training.

Cost and Training Effectiveness Analysis Handbook, U. S. Army TRADOC Systems Analysis Activity, TRASANA Draft Document, July, 1976. The purpose of the document is to provide guidance and assistance to TRADOC personnel in conceptualizing, planning, and conducting cost and training effectiveness analyses (CTEAs).

A CTEA is defined as a methodology which involves documented investigation of the comparative effectiveness and costs of alternative training systems for attaining defined performance objectives, taking into account usage patterns and training scenarios. Three types of CTEAs are identified: the Train-up Study (TUS), the Training Analysis for COEA (TAC), and the Training Development Study (TUS). Chapters 1 and 2 present an introduction and overview of the CTEA process. The remaining chapters treat, on a step-by-step basis, the general procedures comprising a CTEA study. These procedures include identifying the performance objectives, planning the analysis, determining the effectiveness of the training program under study, estimating the true costs of the program, and finally comparing the effectiveness and costs.

Literature Dealing with Valuation Issues. Barsby, S. L. Cost-Benefit Analysis and Manpower Programs, Lexington Books, Lexington, Massachusetts: 1972. A number of cost-benefit analyses as they relate to manpower programs are discussed in this volume. The general categories into which they are divided are vocational education (secondary and post-secondary schools), institutional out-of-school retraining programs under state and federal legislation, and programs with an OJT (On the Job Training) component and miscellaneous programs.

Five studies concerning vocational education in secondary schools and two studies on post-secondary schools are examined. In general, relevant costs included operating expenses, foregone earnings, direct costs borne by students, and tax adjustments for unpaid property taxes. Benefits were typically defined as discounted future earnings.

Studies on institutional retaining programs are divided into those concerning state or Area Redevelopment Act-sponsored programs and more recent studies evaluating Manpower Development and Training Act-sponsored programs. Four studies in each area are reviewed. Generally, costs include operating costs, a portion of state and federal administration costs of overall ARA activities, transfer payments made to trainees while participating in training, opportunity costs, and direct costs to students. Benefits were calculated as discounted future wages.

The last section discusses OJT and miscellaneous programs. Studies that are examined concern the Neighborhood Youth Corps, Work Experience and Training Program, MDTA-sponsored OJT, Job Corps, Bureau of Indian Affairs-sponsored retraining, dropout-prevention program, high school job placement services, and a vocational rehabilitation program.

Harberger, A. C., et. al. (eds.) Benefit Cost Analysis 1971. Aldine-Atherton, Chicago: 1972. This volume contains four papers of interest concerning investment in human capital, a phrase synonymous with training.

- "A Benefit-Cost Analysis of the Upward Bound Program" (W. I. Garms) is an evaluation of that project, operated by the U. S. Office of Education. Individual benefits were defined to include increased lifetime income after taxes, the stipend received while in the program, and scholarships and grants received while in college. Individual costs were defined as the college tuition, extra living costs associated with attending college, foregone earnings while attending high school and college, and foregone unemployment and welfare payments as a result of being more fully employed during his working lifetime. Social benefits are lifetime income differentials of those enrolled in the program. "Unemployment and welfare payments are transfer payments from the social viewpoint. Since they are included in the income series as a reduction in net income differentials, their amount must be estimated and added back to the differentials." The social costs considered are the direct cost of the program to the government, less the amount paid in stipends; cost of the program to particiapting colleges, cost of educating the students in the program, both in high school and in college; extra living costs of students while in school; and foregone income. Experimental and control groups were used in the empirical analysis. Results of the evaluation were not clearcut, tending to support both the positive and negative positions on the value of the Upward Board Program.

- "Economic Returns to Vocational and Comprehensive High School Graduates" (T. Hee, et. al.) is a comparison of vocational and comprehensive secondary education, comparing costs and labor market performances (in terms of earnings and employment) among vocational and comprehensive high school graduates who did not attend college. Multiple regression analysis is used on questionnaire data. The authors conclude that "the monetary returns of vocational-technical graduates are higher than those of comprehensive graduates."

- "Criteria for Public Investment in the Two-Year College: A Program Budgeting Approach" (Harry N. Heinemann and Edward Sussna) is a cost-benefit analysis of education in a two-year college. "Cost projections reflect estimates of size of student body, the ratio of full- to part-time students, and expenditures on tuition and supplies by students, and operating costs and plant and equipment outlays from public funds. To these direct outlays must be added the foregone income of full-time students." Opportunity costs are foregone imputable to a two-year school. Internal rate of return calculations were carried out, indicating a return to students of approximately 18% on their investment.

- "The MITCE Project as Judged by Efficiency and Distributional Investment Criteria" (David O. Sewell) concerns a cost/benefit analysis of the MITCE (Manpower Improvement Through Community Effort) project. Benefits used were discounted incremental earnings. Costs included were the direct costs of training associated with the daily operation of courses, indirect costs incurred by federal and state agencies in program administration, and opportunity costs (foregone earnings). Using present value calculations, the author concludes that "it thus appears likely that the MITCE project satisfies...the minimum condition of acceptability for an antipoverty program: that it should raise the incomes of the poor."

Gay, R. M., et. al., Cost and Efficiency in Military Specialty Training, Rand Corporation, Rand Paper Series P-5160 (Unclassified), January 1974, (AD 786 652). This report deals with the evaluation of specialty training for first-term enlisted personnel. The methodology considered costs of both formal and on-the-job training as well as the returns to training for first-term enlisted personnel. Training is treated as an investment, and the present value method is used for the evaluation. Net return on training is the difference between the present values of benefits and expenditures. Efficiency is defined as "the set of training practices which maximizes the net return to training." Estimation of on-the-job costs are made for specific individuals rather than for the "typical trainee." The trainee's net contribution to his unit over time is compared with his cost to the military over time. A method for measuring the value of the marginal product of the individual is suggested. The authors define the benefit derived by the military from the training of personnel as the value of the labor services provided by the individual in each period. This method was tested on the Aircraft Maintenance Specialists at Norton Air Force Base, California. The study appeared to support the feasibility of the model.

Haveman, R. H., et. al. (eds.) Benefit-Cost and Policy Analysis 1973, Chicago: Aldine Publishing Company, 1974. The volume contains three articles that are relevant to the valuation of training insofar as they deal with the measurement and evaluation of investment in human capital.

- "Social Returns to Quantity and Quality of Schooling: (G. E. Johnson and F. P. Stafford) estimates the marginal social rates of return to quality, as well as quantity, of schooling. With quality measured as expenditure per pupil per unit time, the determinants of hourly wage rates were determined using regression analysis. "The authors find high but diminishing marginal returns to investment in (the quality of education)."

- "A Statistical Analysis of the OEO Experiment in Educational Performance Contracting" (I. Garfinkel and E. M. Gramlich) deals with the hypotheses that private contractors can be more effective in improving the educational status of disadvantaged students than the public school system. The paper reports on an analysis of test data from an experiment sponsored by the Office of Economic Opportunity in performance contracting. Experimental and control groups were used, and Achievement score gains of both groups were compared. Two methodological problems (imperfect matching of experimental and control students and random measurement error) are discussed. Results indicated that the performance contractors were not able tc improve the status of disadvantaged children.

- "Measuring Benefits from Prison Reform: (J. Holahan) discusses the measurement of prison reform and applies the model to an experimental rehabilitative program. "The benefits to society include:

    - o a reduction in forced redistribution of wealth, physical injury and property damage
    - o a lower level of public expenditures on the criminal justice system
    - o increased productivity/earnings and higher employment rates over time
    - o reduction in other social costs of crime such as private crime deterrence expenditures, migration, avoidance of normal activity, etc."

"The cost of recidivism is this model depends on the direct cost of crimes (stolen or damaged property, personal injury, etc.), the costs of police services, the probability of dismissal or of specific types of trials, the costs of judicial process, the probability of a sentence and of specific types of sentences and the costs of the correctional system. It further depends on the probability of recidivism and the additional costs that would involve." The focus of the analysis is on property crime. Results are inconclusive.

ECONOMIC LITERATURE

The economic evaluation literature search revealed a very extensive set of monographs and journal articles dealing with the general principles of program appraisal. An exhaustive biblio-

graphy in this area might easily include upwards of 1,000 entries Time and resources did not permit a review of even a tenth of that literature. Nonetheless, by reviewing survey articles and monographs as well as recognized "classics", we are confident that little of remarkable substance has escaped our attention.

Currie, J. M., Murphy, J. A. and Schmitz, A. The Concept of Economic Surplus and Its Use in Economic Analysis. The Economic Journal, December, 1971. The authors identify the concept of economic surplus as originating with Dupuit (1968) and Marshall (1930) and refined by Hicks (1940-41, 1943, 1946, 1945-46, 1956) and Henderson (1940-41). The four measures of consumers' surplus defined by Hicks include compensating variation, compensating surplus, equivalent variation, and equivalent surplus. The "surplus" area beneath the Hicksian compensated demand curve is an exact measure of the compensating variation. Henderson's position is reported as being that "for any specific question only one of these measures will usually be relevant." Mishan's (1947-48) position is reported as being that "only compensating variation and equivalent variation should be considered . . . 'in all plausible circumstances.' " Applications of economic surplus to issues of resource misallocation and international trade are discussed.

Prest, A. R. and Turvey, R. Cost-Benefit Analysis: A Survey. The Economic Journal. December, 1965. "Cost-benefit analysis (or 'investment planning' or 'project appraisal') is a practical way of assessing the desirability of projects, where it is important to take a long view . . . and a wide view . . ., it implies the enumeration and evaluation of all the relevant costs and benefits." The authors trace the history of cost-benefit analysis beginning with Dupuit's 1844 paper through the (then) present applications to water resources and other practical areas. In an extensive section on general principles, Prest and Turvey identify some of the questions arising in attempting to perform a cost-benefit study, including:

- o "Which costs and which benefits are to be included?
- o "How are they to be valued?
- o "At what interest rate are they to be discounted?
- o "What are the relevant constraints?"

Among the applications areas surveyed by the authors are water, transport, land use, health, and education projects.

McKean, R. N. Efficiency in Government Through Systems Analysis. John Wiley and Sons, Inc., New York: 1958. This volume is one of the seminal works in general public investment evaluation, although its overt focus is the evaluation of water resource projects. Topics addressed include discussion criteria, choice of alternatives, treatment of intangibles and uncertainty, externalities, double counting, and secondary effects. Two case studies in water resource investment evaluation are also presented.

Samuelson, P. A. Foundations of Economic Analysis. Atheneum, New York: 1965. (originally published by Harvard University Press, 1947). This work is one of the modern classics in economics showing the unifying mathematical structure underlying the various branches of economic theory. Topics treated include equilibrium systems, theory of optimization, theory of cost and production, theory of consumer behavior, welfare economics, stability of equilibrium, and dynamical theory. In the author's treatment of some special aspects of consumer theory, he discusses six different measures of consumers' surplus, including the compensating and equivalent budget variations.

Lesourne, J. Cost-Benefit Analysis and Economic Theory. North Holland Publishing Company, Amsterdam: 1975. This monograph, a translation from the French, is divided into two major parts: theory, and applications. The author distinguishes between the theory of the economic optimum, which he calls welfare theory; and the theory of the comparison of economic states, which he calls cost-benefit analysis. Starting from a basic model of the economy which exhibits one time period, no state, perfect prediction, given information and cost-free decisions, Lesourne discusses the analysis of marginal and structural transformations, taxation and extensions to multi-period models, imperfect prediction and non-cost-free information. The areas of applications of cost-benefit analysis discussed include the industrial sector, the transport sector, urban planning, location and regional planning, public health, education, and general administration decisions.

Sassone, P. G. and Schaffer, W. A. Cost-Benefit Analysis: A Handbook. Academic Press, New York: 1978. This monograph presents theoretical treatments of a number of significant topics in cost-benefit analysis, and presents a paradigm for carrying out a cost-benefit study as well. Topics discussed include decision criteria, the identification of costs and benefits, quantifying costs and benefits, shadow pricing, the discount rate, social and environmental impact analysis and sensitivity analysis. The steps identified by the authors as necessary for

carrying out a cost-benefit study include defining the problem, designing the analysis, data collection, qualitative and quantitative analyses, and preparation of a final report.

Mishan, E. J. Cost-Benefit Analysis. Praeger Publishers, New York: 1976. This monograph is perhaps the most extensive current treatment of cost-benefit analysis. The author introduces the subject via discussion of a series of recent cost-benefit studies, including studies of an underground railway and of a tunnel beneath the English Channel. Among the theoretical topics treated are consumers' surplus, producers' surplus, shadow pricing, valuing external effects, investment criteria, discount rates and uncertainty. The concepts of compensating and equivalent budget variations are linked to the notion of consumers' surplus.

The Economics of Public Finance. The Brookings Institute, Washington, D. C.: 1974. This volume is a collection of four essays by Blinder and Solow, Bread, Steiner, and Netzer. Steiner's essay, "Public Expenditure Budgeting", is intended as a broad "statement of the conceptual issues that underlie the analysis of the political - economic process of reaching and implementing public expenditure decisions." He distinguishes between "the theory of the marginal public expenditure . . . (which) takes as given the legitimacy of government activity, and is concerned with how the public decision maker chooses among competing demands for his limited resources . . . and the theory of the public interest . . . (which) concerns the way in which demands for public activity arise, are articulated, and are legitimized." The author identifies the former theory with cost-benefit analysis and proposes a sequential, rather than simultaneous, decision model explicitly considering the roles of Presidential and Congressional actions.

McKean, R. N. Public Spending. McGraw-Hill, New York: 1968. This monograph deals with both the positive and normative aspects of government spending. The former is descriptive while the latter is prescriptive. One of the topics in the latter realm is cost-benefit analysis. "Cost-benefit analyses are attempts to estimate certain costs and gains that would result from alternative courses of action . . . . The term . . . was originally associated with natural-resource projects but has gradually come to be used for numerous other applications . . . All (cost-benefit) analysis involve working with certain common elements:

- o "objectives, or the beneficial things to be achieved
- o "alternatives, or the possible systems or arrangements for achieving the objectives
- o "costs, or the benefits that have to be foregone if one of the alternatives is adopted
- o "models, or the sets of relationships that help one trace out the impacts of each alternative on achievements (in other words, on benefits) and costs
- o "a criterion, involving both costs and benefits, to identify the preferred alternative."

" . . . cost-benefit analysis necessarily involves groping and the making of subjective judgements, . . . (as well as) an awareness that incommensurables and intangibles are pervasive."

Baumol, W. J. Welfare Economics and the Theory of the State. Harvard University Press, Cambridge, Massachusetts: 1965. In an extended introduction, the author summarizes the significant advances in welfare economics occurring between 1950 and 1965. Among these are the welfare applications of activity analysis by Koopmans (1951, 1957), Arrow (1951) and Debreu (1959); the direct application of welfare economics concepts under the rubric of cost-benefit analysis by Hitch and McKean (1954), McKean (1958), Eckstein (1958), Krutilla and Eckstein (1958), and Hirshliefer, DeHaven, and Milliman (1960); the refinement of the concept and applications of externalities by Meade (1952), Scitovsky (1954), Buchanan and Stubblebine (1962), Whinston (1962), Davis and Whinston (1962) and Coase (1960); and further developments in the theory of the state by Marglin (1963), Baumol (1963), Downs (1957), Olson (1965), and Buchanan and Tullock (1962).

The author's development of a theory of the state is based on "an attempt to determine which, if any, are the circumstances in which the people composing an economy will find that a particular extension of the authority of their government is requisite for the most efficient pursuit of their own economic interests." Baumol employs the externality argument to circumscribe, in general terms, the duties most efficiently relegated by the private sector to government.

McKean, R. N. (ed.) Issues in Defense Economics. Columbia University Press, New York: 1967. This volume contains eight

papers dealing with the general topic of the use of economic analysis in military decision making. Malcolm W. Hoag in "Increasing Returns in Military Production Functions" argues that "prominent production economies of scale do apply with special frequency in military applications, and that they can join with combat conditions to create increasing returns to scale that demand wide-ranging nonmarginal analyses of military alternatives."

Martin J. Bailey in "The Market Mechanism in the Defense Department" explores the history, potential use, and pros and cons, of the use of "transfer prices" within the military to guide resource allocation.